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INTEGRATING ERGONOMICS AND WORK SAFETY INTO CAR MAINTENANCE OPERATIONS

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Abstract

The goal of this research was to apply the appropriate principles of Human Factor and Ergonomics to creating a safety management system which makes maintenance activities safer and is consistent with the nature of the operations of the client. The client of the thesis was Speed Autokorjaamo, a small and independent car maintenance company based in the industrial area of Kuromajaantie, Jyväskylä. The company's maintenance operations is supported by equipment, machines and well-trained technicians.

Relevant theories of Human factor and Ergonomics such as human-system compatibility, biomechanics, human error theories and symvatology were gathered to extract applicable ergonomics principles. Furthermore, Occupational Safety and Health regulations in the EU and Finland were researched to provide guidance in evaluating the current operations.

A risk assessment of the current maintenance operations of the client was done to have a blue print of the current operations. Several options existed to improving safety in the company and these options were explored. An existing management system for a SME company was not identified, However, there were options to designing one.

The outcome of the research raised several issues about the applications of safety principles and theories to a small scale company with a limited budget like the client.

Keywords
Human Factor and Ergonomics, Symvatology, Biomechanics, Risk, Hazard, Occupational safety, Compatibility, material handling

Miscellaneous

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Abbreviations

HFE	Human Factors and Ergonomics
NIOSH	National Institute for Occupational Safety and Health
SMEs	Small and Medium Enterprises
HASAWA	Health and Safety at Work
PPE	Personal Protective Equipment
OSH	Occupational Safety and Health
ISO	International Standard Organization

1 Introduction

This research is based on a response to the gaps the author observed while working as a maintenance trainee undertaking his practical training as requirements to bachelor's degree in Logistics engineering (JAMK University of Applied Sciences 2014). The thesis client is Speed Autokorjaamo located in Jyväskylä, a car maintenance and service company.

In the author's observations, during his training in the company, were the absence of a defined maintenance safety system and an equal lack of compatibility between tools, machineries, equipment, work environment and maintenance persons. There was an unwritten, general understanding among maintenance technicians on issues of work safety and equipment handling- and this was usually well emphasized before undertaking a maintenance tasks. However, that was where it ended. The consequences of these were:

- A hazard-inherent operations that could cause an accident at any moment and endanger lives
- A man-machine crises
- Unreported and undocumented accidents and near-misses
- Work inefficiency
- And an unusually high employee Turn-over.

The human-System interaction is critical to optimizing both human and system's well-being and performance (Salvendy & Karwowski 2006, 23), whilst in the past, human has been fitted to predesigned systems, machine design engineers frequently produce machines which places the operator under considerable stress (Stranks 2010) the outcomes have been a crises leading to accidents, poor performances, injuries and in some cases death.

In maintenance operations the need for ergonomics and work safety cannot be overemphasized. Every year, a large number of people get seriously injured and maimed at work. One major factor contributing to work place accidents is engineering safety and it has become a critical focus because of the inherent risks in engineering products and operations. For example, the day Stephenson's first railroad line was dedicated to public use; a fatal accident killed a prominent English legislator (Dhillon 2005, 170). The more sophisticated engineering products have become, the more complex and challenging had been the maintenance operations and safety issues.

Therefore, this is a qualitative case study research that studied the human factor in the elements of a maintenance system with the intent to enhancing the safety and ergonomics of the operations. The author strove to integrate the principles of Human factor/Ergonomics and work safety into creating a safety management system suitable for the company's operations.

1.1 Background and Objective of the Thesis

Maintenance is a collective term that denotes a variety of activities in different sectors and all kinds of working environment. Specifically, in the auto industry, maintenance assumes an important task especially when a car is seen as an engineering product of multiple-system assembly. But the influence of maintenance goes beyond the engineering product. A correctly planned maintenance ensures the safety and well-being of the technician as well as the environment (EU-OSHA, European Risk Observatory Literature Review 2010).

Between 2005 -2006, 18%-19% of all accidents in Finland were related to maintenance operations (EU-OSHA, European Risk Observatory Literature Review 2010, 7-8). Additionally, in all EU countries, maintenance, repair tuning and adjustment is fourth on the list of top 10 working processes accounting for the highest number of fatal accidents over 2003-2005 (EUROSTAT-ESAW). However, the cost of work-related injuries and illness can be substantial, especially to SMEs. In the EU-27 in 2007, 5.580 accidents at the workplace resulted in death. The consequences are far-reaching and could be disastrous to growing micro firms like Speed Autokorjaamo.

Human factors and Ergonomics is quite a vast discipline that cuts into many professions including engineering, the principles are applicable to engineering designs including car making. However, it is intensive and expensive in application because it requires wholesome changes and redesigning of operations. The aviation industry employs the theory of HFE in aircraft maintenance and work center designs but very little work has been done to the car servicing outlets, dealerships and SMEs.

Therefore the goal of the research was to apply the appropriate principles of human factor and Ergonomics to creating a safety management system consistent with the nature of the client's maintenance operations with regards also to the company's financial budget.

To achieve this, the following objectives were outlined:

- Evaluate the company's existing ergonomics and work safety in maintenance operations
- Gather appropriate and applicable theories of human factor and ergonomics as well as Finnish/EU existing laws and regulations of employee safety
- Create a safety/ergonomics management system and evaluate the cost to the company

The result of this thesis will be of particular interest to SMEs who wish to ensure employees health and well-being whilst not endangering the company's financial statue.

1.2 Research Problem

To meet the objectives stated, it is necessary to create relevant research questions that provide data and information for the building of a management system for Speed Autokorjaamo. The following questions were formulated;

- What are the risks factors and hazards presently visible and hidden in the maintenance operations?
- What are the explorable options to improving ergonomics and work safety?
- Is it possible to integrate these options and at what cost to the company?

1.3 Limitations and Inclusions of the Thesis

This thesis is mainly focused on the maintenance operations of Speed Autokorjaamo, observed behaviors of technicians doing their designed tasks and jobs. The research did not focus on redesigning the work center and strategies for designing work centers. Personnel training on human factors applications were not undertaken. The aspect of ergonomics that deals with engineering design for comfort and applying human factor principles during system acquisition were not considered either.

The research focused on factors related to manual material, tools and equipment handling (lifting, handling, pushing and pulling), situation awareness on the job, postures, tasks and jobs redesign and environmental factors. How the company handles and disposes engineering wastes were also critical to the research findings.

1.4 Contribution of the Thesis

The findings and the compiled document from the study formed a customized safety management system that Speed Autokorjaamo has begun to analyze with the intention of integrating it to its operations.

1.5 Company Profile

Speed Autokorjaamo is a car servicing and maintenance company located in the industrial area of Kuormajaantie, Jyväskylä, central Finland. Established in 2004 in Laukka, Central Finland, the company moved operations to its present location in 2014 due to increasing demands for services within Jyväskylä.

The company has in employment six staff (including maintenance technicians and a management person). According to the EU User Guide on defining SMEs it can be classified into micro, small and medium enterprises (SMEs):

> *Micro enterprises are defined as enterprises which employs fewer than 10 persons and whose annual turnover or annual balance sheet total does not exceed 2 million euro (Extract of article 2 of the Annex of Recommendations 2003/361/EC).*

The company sits on a property of 250 square meters and boasts of modern facility and engineering equipment with which services could be carried out effectively. The company has become the preferred choice of students from universities and technical colleges in Jyväskylä for practical training and gaining of experience for working life.

1.6 Operations and Services

The company offers services which can be categorized into:

Maintenance Tune-up: (this is also known as a major service) this is a regular maintenance performed on a car after certain reached mileage in the history of the car in most cars this is usually after 2 years or 48.000km. Usually, the car manual gives instructions on what parts of the car should be changed and when a tune-up maintenance should be performed. The manufacturer's manual for the car gives detailed explanation on these maintenance tasks and checklist which is followed by the engineering technician. (Chase 2006, 74.)

Repair/Corrective Maintenance: repair maintenance is required when a detected or an undetected fault in a car not corrected causes significant damage to the car. For instance a leaking master cylinder of the brake system could lead to low brake pressure and significantly damages the brake pads. Usually independent car repair shops undertake this maintenance most of the time. (Tim Gilles 2012.)

Fleet Services: A fleet is a group of several vehicles owned by a company, utility or municipality (government). To service and maintain these kind of vehicles require a maintenance schedule and time management. The company is notified about such demands of service in time so that needed equipment and personnel are allocated for the job and a defined maintenance schedule prepared for the tasks. The services can include inspection, repairs, tune-up maintenance, oil changes and others. (Tim Gilles 2012.)

Seasonal Services: these services include changing of winter and summer wheels, fixing mud covers, engine guards, checking heating system, air pressure checks, windshield checks amongst others.

1.7 Method

The term qualitative research is the most often used tool in social sciences in contrast to quantitative research which tends towards scientific topics and hypothesis. One way of differentiating qualitative research from quantitative research is that while the former tends to explore phenomenon, trends and behaviors in a sample or population, the latter aims to test hypothesis. (Clayton 2010, 95-97.) However, both have been employed scientifically to explain trends and answer hypothesis questions. Both qualitative research and quantitative researches can be systematic and scientific, hence qualitative research is equally applicable to scientific case studies (Verbe, King & Keohane, 1994).

To answer the research questions, the methods of qualitative research were used. And these methods included:

- Participative Observation: the author undertook roles in the engineering team to gain useful knowledge into the state and mindset of the company's technicians towards safety and ergonomics at work. (Clayton 2010, 95–97.)
- Interviews: the author held interview sessions with the team leader of the engineering unit and other technicians. Interviews provided knowledge into the company's philosophy, objectives and goals.
- Document studies: the author undertook the tasks also of reading through documents and files of the company. Mainly, the manufacturer's manuals of all equipment, tools and machines the company uses for maintenance were carefully studied for needed information as regards ergonomics and safety.
- Questionnaire: the author formulated relevant questions about safety and ergonomics of tools environment, work and machines. The questionnaires helped gathered information from other Autokorjaamo about existing safety management systems to enable for benchmarking.

2 Theory

Over the past 50 years, *ergonomics*, a term that is used interchangeably with *human factors* (denoted with HFE) has been evolving as a unique and independent field of science and profession that focuses on the interactions between human and artifact viewed from the unified perspective of the science, engineering, design, technology and management of human-compatibility systems, including a variety of natural and artificial products, processes, and living environments. (Karwowski, 2005.)

The International Ergonomics Association (IEA, 2003) defines ergonomics (human factors) as the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. In the United States which was the origin, and a few other countries, it is popularly referred to as Human Factors while in Europe and all other countries it is called Ergonomics (Sanders & McCormick 1992, 4-6).

The current interest in Human factors and Ergonomics stems from the frustrations humans and most specifically machine and tools technicians have experienced from poorly designed or badly installed machines and systems at workplaces and offices. Daily, these frustrations have translated into (a) loss of meaningful work hours (b) accidents and disasters (c) inefficiencies and poor job satisfaction. If you have you ever used a tool or machine and wondered how a dumb way to design such equipment? Then you have experienced the numerous frustrations people encountered at their jobs if Human capacity and ability is not carefully considered in assembling a work center or equipment (Sanders & McCormick 1992, 4-6).

The increasing advancements and breakthroughs in inventions and technology have created a complexity in engineering designs and an almost impractical user-friendly philosophy both to the machine operators and maintenance persons. The cost of retrofitting is often exorbitant and intensive. Hence there is the need to involve ergonomics in the design stage.

Traditionally, the branches of specialization within Ergonomics most recognized are physical, cognitive and organizational ergonomics. *Physical Ergonomics is concerned primarily with human anatomical, anthropometric, physiological, and biomechanical characteristics as they relate to physical activity.* (Chaffin & Anderson, 1993; Karwowski & Marras 1999; Phesant, 1986.) *Cognitive Ergonomics focuses on mental processes such as perception, memory, and information processing, reasoning and motor response as they affect interactions among humans and other elements of a system* (Diaper and Stanton, 2004; Hollnagel, 2003; Vicente, 1999.) *Organization Ergonomics (also known as macro ergonomics) is concerned with the optimization of sociotechnical systems, including their organizational structures, policies, and processes* (Holman, 2003; Nemeth, 2004; Reason, 1999.)

2.1 Contemporary Ergonomics

Contemporary ergonomics concerns the discovery and application of information about human behavior, abilities, limitations and other characteristics when designing machines, systems, jobs, tools, tasks and environments for productive, safe, comfortable and effective human use (Sanders et al. 1993; Helander, 1997b.) In this context, contemporary ergonomics covers a wider range of engineering, systems, human abilities, safety, comfort and efficiency. This is becoming a focus area for companies and businesses which value its human resources and is human-centered in organization, planning and operations.

While in the past, ergonomics has been the objective in a technologically-driven invention and design era (reactive design approach), in the future, ergonomics should take the driving seat and become subjective in all approaches of system design and engineering product acquisition (proactive design approach) (Gravriel & Karwowski 2006, 6-10). To gain a better concept of the interrelations and the enormous role humans play in an engineering design, the theory of human-machine interaction is critical to human factor and ergonomics and the principles can be well applied to systems acquisition and design process of engineering products.

2.2 The Evolution of Human-Technology Interaction

Originally, ergonomics focused on local human-machine interactions, this meant that the level of skill, knowledge and capacity an operator possesses in operating a machine in his job was central to the study of ergonomics. Then it evolved into study of human-machine system interaction*. A system is a construct whose characteristics are manifested in physical and behavioral phenomena* (Meister 1991). The traditional concept of human-machine system is an organization of people and the machines they operate and maintain in order to perform assigned jobs that implement the purpose for which the system was developed (Meister 1987).

In the Human-machine systems interaction, there exist activities undertaken by the human function which involves processing of information, decision-making, memory, attention, feedback and human response process. And Karwowski (1992a) broadly shared these activities into;

- Tasks that produce force (primary, muscular work)
- Tasks of continuously coordinating sensory-monitoring functions (assembling or tracking tasks)
- Tasks of converting information into motor actions (inspection task)
- Tasks of converting information into output information (required control tasks)
- Tasks of producing information (primarily creative work)

However, HFE has come a long way and evolved as more and more discoveries and theories have been formulated. There have been the studies of technology-system relationship as well as human-system relationship. Each era of study giving more insight into the field of ergonomics and providing the spring board for the current direction of the study. Today the focus is on broadly defined human-technology interactions. (Gravriel & Karwowski 2006, 5-10).

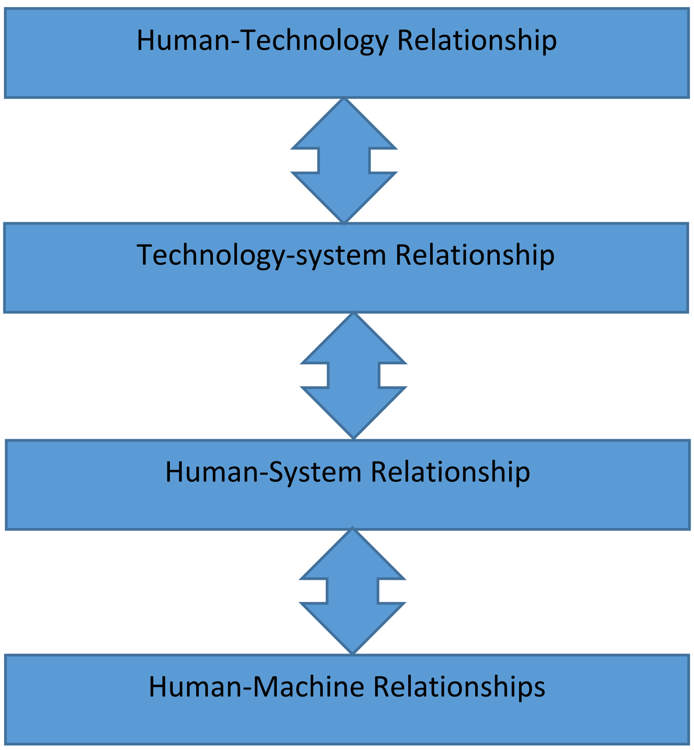

Figure 1 Expanded view of the human-technology relationship (Mesiter, 1999)

2.2.1 Systems

A theme that will most often reoccur in the discus of Human Factors and ergonomics is the system. Various definitions have attempted to explain what a system is, however for the sake of this thesis I have referred to the Farlex Free Online Dictionary (2014) for a most suitable definition:

> *A system is a group of interacting, interrelated, or interdependent elements forming a complex whole.*

In other words a system is an entity that exists to do certain tasks (Bailey 1982). Therefore, a system could be composed of humans, machines, components working together as a unit to achieve tasks which an independent component cannot achieve alone. In contemporary HFE, the term human-machine system is critical to understanding ergonomics practices. The human-machine system is combination of one or more people with one or more physical components working in synchrony to bring about desired output. However, the true meaning of a machine is lost in this statement. A machine does not necessarily imply a complex multi-input device; rather, it could go as simple as a student's pen, a farmer's hoe, a cooker's pot or an accountant's calculator. The more complex machines are for example the airplane's cockpit, automated production line, the car engine amongst others. The word interaction in a system is simply the kind of input and output methods the system recognizes to function well. Systems, based on the level of interactions can be classified into three kinds:

Manual system: this consists of an interaction between the human and a simple hand-coupled tools like hand tools. Examples of such tools are screw driver, a pen, a knife, a hammer, or a spanner. In which case, the operator requires their won physical energy as the source of power to operate these tools.

Mechanical System: this can also be called semi-automatic systems and involves the elements of well-integrated physical parts such as types of powered-machine tools. The power to operate them is provided by the machine and the function of the human is to control the inputs by the use of control devices with minimal use of self-strength.

Automated System: this is when a system performs all operational functions without the interventions of humans. The consequence of this is the misconception that since little human intervention is required the system could function on its own like human. This is not true. The automated system requires input parameters which the operator has to key into the control device, as well as maintenance, installations and programming. (Sanders et al. 1993, 12-16.)

2.2.2 Characteristics of a System

Systems are Purposive. A system is designed to fulfill certain operational functions and purpose or else it is nothing more than a collection of disjointed outputs. It is the same as a system must have a goal, an objective or a set target to exist as a system.

Systems operate in an environment. Everything outside the physical boundaries and space of the system is its environment. Otherwise if there is not distinguishing boundary between the system and the environment, the environment is an integral part of the system.

Components serve functions; the components of the system are interdependent and work for a general purpose function. No component acts or works in isolation of the general system. Otherwise it is not a part of the system anymore. There are four basic functions of a system identified by Sanders and McCormick: sensing (receiving information), Information storage, information processing and decisions, and action function. (Sanders et al. 1993, 16-21.)

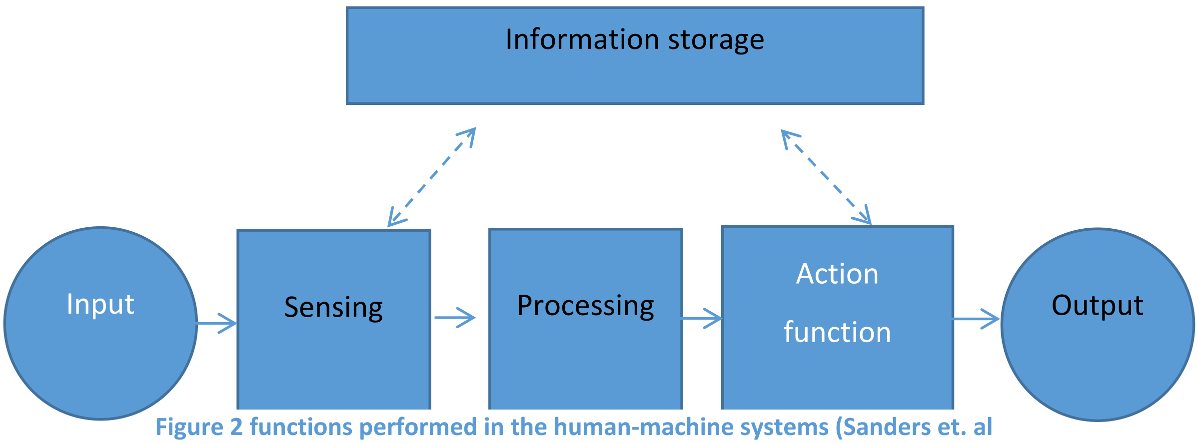

Figure 2 functions performed in the human-machine systems (Sanders et. al 1993).

Systems can be hierarchical: it is quite common for systems to be made up of multiple sub-systems. This means that in a system are other systems. To put this clearer, a component in a system could as well be an integration of sub-components; hence the system has sub-systems within. In describing a system, the question could be asked: How low can we go in the analysis of a system?

Systems Interact: the components of systems and sub-system work together as a unit to achieve the goal of the system, without that interaction and inter-operation, the system cannot be called a system but independent component.

2.2.3 System Reliability

System reliability refers to the degree of dependability of performance of a system, subsystem or system component in executing the purpose for which it is created for a certain period of time. The measure of reliability is a probabilistic certainty that a system will be successful or fail in task execution. It also important that if a system includes two or more components (human and machine), the reliability of the whole system depends on the reliability of the individual system components, in which case, is man and machine.

Reliability of a component is the probability that it does not fail, and it is defined by $r = 1 - p$; where p represents the probability of failure and r the probability that it does not fail. The tendency of a complex system to fail is a function of the probability of individual components failing. The more components a system has, the more likely it will fail from the failure of an individual component. Likewise the overall system reliability is a product of the reliability of the individual components.

Generally, components and subsystems in a system are basically arranged in two patterns-series and parallel arrangement. Components when arranged in series meant that the successful performance of the system depends on the performance of individual components of the system. For example, an operator who runs a production milling machine and the machine are in a series arrangement. The concentration of the operator as well as the working condition of the machine determines the performance of the system. The conditions for a system to be classified as series arrangements are that (a) the component failures are independent of each other and (b) failure of an individual component results in overall system failure.

The parallel arrangement is often used if the overall system failure is considered critical to the output or desired result. In such systems, there are usually two or more components performing same function. This can be referred to as back-up or redundancy arrangements. An example would be three conveyor belts supplying raw materials to a collection Vat. The system would fail only if all three conveyor belts failed. In parallel arrangements, the failure of all components performing similar functions means that the system will undoubtedly fail. (Sanders et al. 1993, 16-21.)

2.2.4 Human Reliability

The incidence of human error has been on the rise since the introduction of complex engineering products in industries, so as well has raised the costly consequences. The losses have claimed human lives, rendered skillful workers invalid, loss of intellectual property and financial capital. It has been estimated that human error accounts for 60-90% of major accidents and failures in complex systems (Wickens & Hollands 2000). This has given prominence to the study of human error within HFE.

Human reliability is inextricably linked to human error. And *Human error is an inappropriate or undesirable human decision or behavior that reduces or has the potential for reducing effectiveness, safety, or system performance* (Sanders et al. 1993,). From this definition, it can be deduced that an error becomes a failure if it influences or hinders overall human-machine system well-being and performance. A maintenance technician, who forgets to put on his safety shoes and hand gloves, lifts a load without regards for his own safety could be considered an error and compromises work safety. All errors do not necessarily result in accidents, but they are still errors nonetheless.

Human errors are not peculiar only to system operators alone, it could as well come from system's designers, maintenance persons, managers, supervisors and accounting personnel. Therefore, in considering human reliability analysis in a company from human error approach, it is appropriate to consider the whole system and not focus on a department alone.

Rasmussen (1987) identified the need for a company or firm to define what a human error means since it is possible to commit an error and not identify it as an error. It requires a careful, rational evaluation of events leading up to the error and setting of a standard of performance required of all parties in executing set commands. This is because human error tends to be arbitrary. He recommends a thorough investigation be conducted and the error must be studied in the light of other factors and not treated in isolation. Then it is possible to trace the source of the error which could be poorly designed tools, faulty equipment, badly designed work centers or poor management practices.

Over the years, Ergonomists have attempted to classify human errors. The following are the most popular classification of human errors according to Swain and Guttmann (1983);

- Errors of omission
- Timing errors
- Errors of Commission
- Sequence Errors

Errors of Omission is a failure on the part of a person to do something or neglects a sentence in a set of commands.

A timing error occurs when a person *fails* to perform a tasks or commands within the allotted time for the command either because they have acted too late or too early. For example a nurse administers a drug too early or too late in a surgical procedure, there is the tendency to put the life of the patient in danger.

Errors of commission involve performing a command wrongly or incorrectly. For example lifting a three Ton car on a wench and not lifting it on all four posts because of the time it will take to properly align all four posts is considered an error of commission.

Sequence Error is an off shoot of error of commission. This is the skipping of a command in a sequence of commands when performing a task (Sanders et al. 1993.)

2.3 Human-System Compatibility

Human Factor and Ergonomics advocates systematic use of knowledge concerning relevant human characteristics to achieve compatibility in the design of interactive systems of people, *machines, environments and devices of all kinds to ensure specific goals* (Human factors and Ergonomics Society (HFES), 2003). The term compatibility between system and human is one critically important concept to understanding the objectives of HFE. Although as stated above, from the goals of HFE, systems improvement, worker safety, quality of life and system, ease of performance, and productivity are the main objectives, however, these goals cannot be achieved without resolving the existing incompatibility between human and the machine. Karwowski (1997) advocated for the term human-compatibility systems, to drive home the need to focus study on the extensive, multi-faceted nature of compatibility that exists between man and his working systems. Broadly speaking, the performance of the human is an outcome of the existing compatibility between him and the system. There always exist two factors to this equation- the limitations and the capacity of individual worker, as well as the affordance of both technology and environment. The result is a series of negatives and positives which makes the human-machine system complex and needing careful analysis to make profitable trade-off.

The American Heritage Dictionary of English Language (Morris 1978) defines compatibility *as (a) capable of living or performing in harmonious, agreeable, or congenial combination with one another and (b) capable of orderly, efficient integration and operation with other elements in a system*. To achieve compatibility in and minimize system crises between the human-machine interactions, there has to be a consideration for the limitations both individuals (man and machine) bring to the system. The outcome is a series of positives and negatives which defines the overall system's well-being. The positive outcomes include work productivity, performance, job satisfaction, work safety, life and product quality. The negative outcomes are accidents, injuries, low productivity and quality of life and product. (Salvendy et al. 2006, 10-12.)

2.3.1 Symvatology-Science of Compatibility

The system (machine, environment, equipment, tools and organization)-human relationship can be chaotic, unpredictable and often non-linear and requires a specialized approach to the study of it. Karwowski (2001) proposed the need for a corroborative science that can help analyze and build a theory for this phenomenon. This sub-discipline is called

Symvatology, the science of artifact-human (system) compatibility. The theory develops a quantitative matrix for measuring the degree of artifact-human compatibility.

Karwowski coined the words from two Greek words- *Symvatotis* (compatibility) and *logos* (study, reasoning or logic). *Symvatology is the systematic study (which includes theory, analysis, design, implementation and application) of interaction processes that define, transform and control compatibility relationship between artifact (systems) and people.* (Salvendy et al. 2006, 9-25.) According to the theory, an artifact system consists of designed objects and machines made by man and operating in an environment and space. The human system is the man- operator, team leader, technician, a farmer or all profession that requires the use of a tool for achieving goals. The systematic study, analysis and quantitative measuring of all factors contributing to this relationship gives useful insights into how performance can be enhanced and instability in the system minimized. This study also provides solutions to avoiding work place accidents and injuries and avenues to enhancing work satisfaction.

Karwowski and Jamaldin (1995) represented an artifact-human system as a construct that contains a human subsystem, an artifact subsystem and an environmental subsystem all interacting within a set space in a period of time. This is a phenomenon that is constantly dynamic and tends towards complexity and chaos. However, the degree of complexity of a system is likely to make the system tends towards low compatibility.

The level of conflict or compatibility in the system (Entropy) depends on the degree complexity or simplicity of the system. Karwowski, using four pairs of factors to denote the state of the system in all conditions identified (complexity, Compatibility), (high, high), (low, low), (high, low) and (low, high). However, it should be noted that not all transformation from a high to a low level of system complexity necessarily translates to improved compatibility of the system (Karwowski & Salvendy 1988).

Karwowski and colleagues (1988, 1994a) proposed the *complexity-incompatibility principle* which states that *as artifact –human system complexity increases, the incompatibility between system elements, as expressed through their ergonomics interactions at all system levels also increases, leading to greater ergonomic entropy of the system and decreasing the potential for effective ergonomics intervention.* He experimented this using a simple chair and a swivel chair with handles and height adjusters. The one simple chair a simple design and the swivel chair a complex design. The Ergonomic intervention (E_s) is found to be more effective when applied to the simple chair than the swivel chair. Likewise, the entropy (E_{h2}) of the complex chair tends higher and incompatible (E_{s2}) to the system when compared to the simple chair.

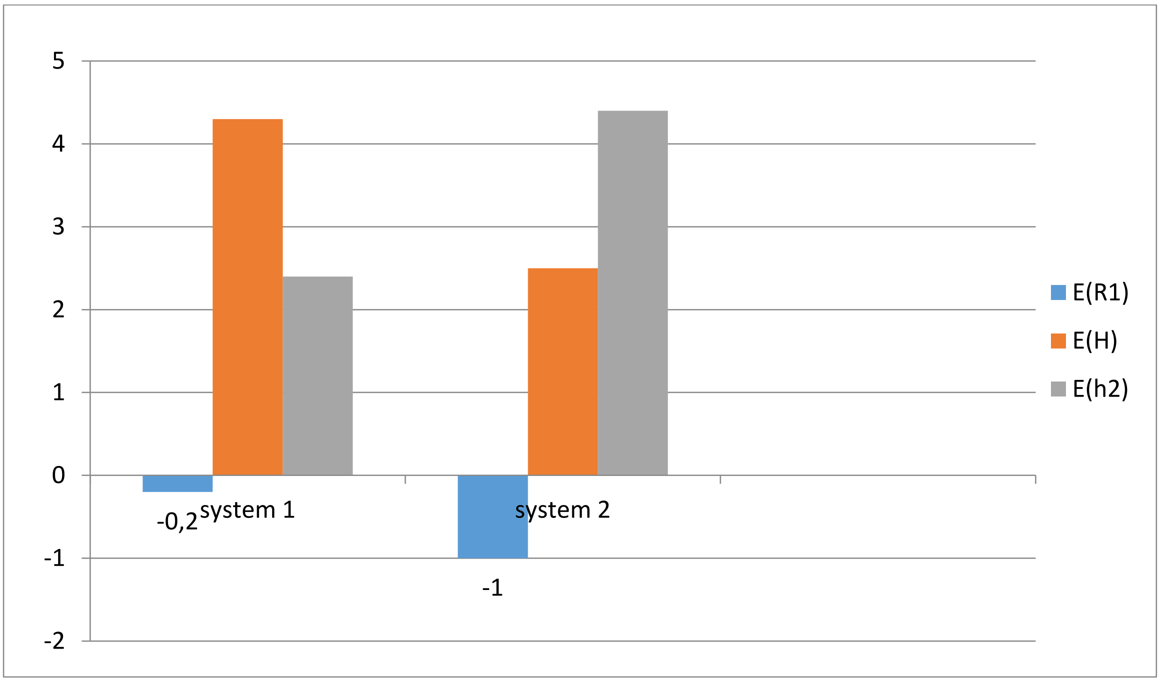

Figure 3 System entropy determination: example of a chair. (Karwowski, 2002.)

The paradox in this phenomenon is that adding functionality to an existing or new artifact comes with the trade-off of increased complexity. And it is expressed in the frustration and difficulty of handling and operating the artifact which could have enormous impact on work efficiency, job satisfaction, safety and well-being at work and the level of error encountered during operations of the system.

2.3.3 Compatibility in Ergonomics Design

Ergonomists and HFE professionals concern themselves with interaction of artifact and human and not general system design. To achieve this, the professional must familiarize himself with requirements and functions which are indices for building human-artifact interaction. Human capacity and limitations relative to the environment and the artifact are an important factor to consider during the design process.

Suh (1999. 2001) proposed a frame for axiomatic design which uses four different phases that makes a mapping of identified needs and ways to achieve them:

(1) Customer requirements, which is customer needs or desired attributes
(2) Functional domain, which is functional requirements and constraints
(3) Physical domain, which is physical design parameters
(4) Processes domain, which is processes and resources (Salvendy et. al 2006, 25-28.)

Karwowski in 2005 redefined the four phases into the following concepts:

(1) Human factor and ergonomics requirements which is redefined to human needs and system performance
(2) Functional requirements and constraints rephrased into human limitations and capacity
(3) Physical domain expressed in terms of human-system interactions and compatibility
(4) Process design which is the management of the human-system compatibility.

However, following Karwowski (2005) proposition, ergonomics design has shifted paradigms towards axiomatic design. Axiomatic design is better expressed in mapping functional requirements to design limitations and parameters. The relationship is expressed in matrix formations for easy manipulations of these parameters to achieving system compatibility.

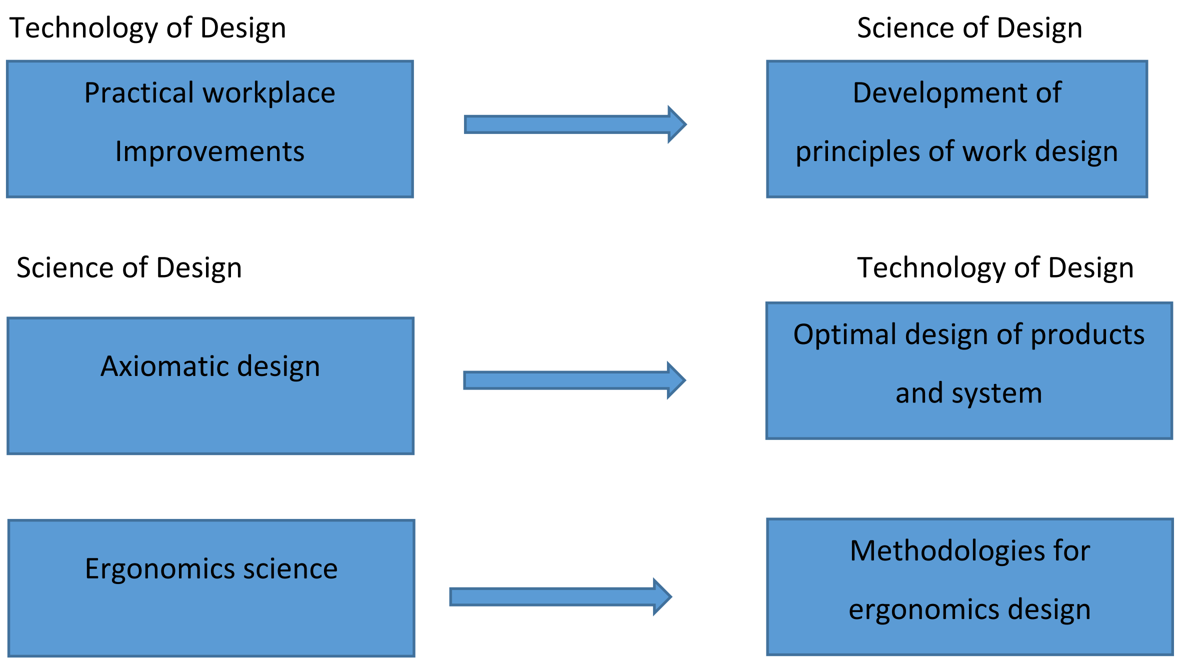

Figure 4 Axiomatic Approach to ergonomics design (after Karwowski, 2005)

2.4 Balance Theory-based Model

Every work environment conceals risks and hazard to the worker. There is no perfect workplace that provides full job satisfaction, ideal psychosocial conditions, and free of all work related hazards. Every element of the work system is in constant interaction, and theses process creates a state of working condition that endangers the life and well-being of workers. Therefore the need to consider the trade-offs between working system components when making ergonomics improvement in the system is recommended so as to create a balanced working system that engages all necessary components of the system to make the workplace a better place. The term work place compatibility between the worker and the work environment is the foundation for this theory.

Smith and Sainfort (1989), conceptualized the balanced based theory model, they took a system's approach by focusing on the elements of the work system and arriving at conclusion that the system comprises of five interacting factors or components:

- Employees
- Work Environment
- The organizational or corporate processes
- Tasks

- And Technology

Smith’s proposition was that in the middle of these interactions is the human, who himself interacts with all factors of the system. The interactions between components and other components produce risks for employee safety and health. It must be mentioned that the human as a factor of the system also engages in risky choices that endangers other factors in the work system too.

2.4.1 The human Factor

At the center of the work system is the human who executes job tasks under the direction of the organization’s policies. There exist several approaches to analyzing human behaviors that exhibits risks and hazards which causes accidents and injuries to him and others. There is also the approach of misfits between the worker, his tools and the environment which creates hazards and risks for accidents. However, Smith (2003), proposed the theory that the employee stands as a critical factor in promoting work place safety, control of hazards and improving occupational health. He proposed certain changes in behavioral safety that can enhance employee behavior and improve safety at work.

Identifying that the employee is the critical point as well as the initiator of interactions between hazards and unsafe acts that produce accidents is the right approach to enhancing work place safety and occupational health. The Organizational hierarchy must identify this, as well as put up policies and measures that educate, empower and increase awareness of the worker to the significant role he plays in hazards interactions. Traditionally, employee error has always being viewed as criminal in most company policies and the worker ostracized by the management and his co-worker. This approach increases unsafe behaviors because it tends to instill fear into other workers about the grave consequences of operational error. However, fear only increases the chances for more errors.

The first action Smith proposed is that organization’s management must identify the need to empower employees to actively participate in managing risks that come with tasks execution. An awareness of the hazard he encounters minimizes the chances of causing accidents. Smith advised that organization’s management makes effort to create a channel of communication between employee and management for reporting hazards, injuries and near-misses. This will go a long way in curbing impending occupational hazards both to human and equipment.

Secondly, numerous theories of accident causations have identified the unsafe behavior of the worker as the primary source of accidents. Other theories identified human error as the source of workplace accident, while other see the level of skill of the worker in tools and machine handling as the cause of work place disaster. However, central to all these discuss, is the behavior and choices of action of the worker in the workplace that is the major contributor to accidents. Smith Proposes that employees be trained in such topical issues as situation awareness, identification of hazards and risky behaviors that endanger life and property. The employee behavior must be put at the center of accidents prevention. Of course some hazards cannot be completely eradicated, and this is due to fact that the employee is constantly interacting with the tools and gaining new concepts on machine use. However, empowering the worker through trainings, seminars, warning signs at work places or accidents report put the worker in a state of constant awareness of the dangers his choices create for the entire system.

2.4.2 Environment factor

The work environment embodies the system of operations by defining the system's boundaries and limitations both in space and geography. The degree of exposure of hazards to the worker at the work place varies from industry to industry, job description to job description, tasks to tasks. The degree of exposure of hazards to a lawyer in a law court widely differs from a maintenance engineer working in an off-shore oil rig. To effectively make the work environment safer for the worker, organizations must comply with safety and occupational health codes and policies as stipulated by a governing body's regulations. Coupled with this, must be a periodic inspection of work place hazards, an accident investigation if an accident has occurred, a report statement of the level of conformity of the organization to work place safety policies. The company should ensure that new equipment purchase and installation comply with safety codes and ethics of the industry.

2.4.3 The Organization factor

Smith, Cohen and Cleveland (2005), established that successful occupational safety, health and well-being programs succeeded in those companies that had a commitment to minimizing work place risks and hazards. Corporations with less commitment or an undefined program for addressing occupational accidents and injuries tend to have a poor safety record. When safety culture is absorbed into a company's operations, from the factory floor to top hierarchy of management, this builds a foundation for a strong employee commitment to ensure work place safety.

The first trace of corporate commitment of an organization to occupational safety and health is a policy statement from the top echelon of management stating the company's support for occupational safety and health. The policy statement states in clear terms the roles of each employee in the pursuance of safety and well-being of employee and work environment. For achieving or failing in certain safety objectives and targets, the policy highlights incentives, benefits, costs and punishments to the employee and work department from which such feats have been achieved or broken. In essence, the organization establishes a safety culture that transcends to all department, sections and units which guides employee behaviors at work place.

Second trace of a corporation's commitment and responsibility to occupational health and safety is the creation and promotion of communication channels at all levels of management in which the employee at the lowest level of organizational hierarchy can communicate his thoughts, observations or ideas to the very top management personnel. The sole purpose of this is that hazards at work place are quickly identified and communicated to all levels of operations so that prevention measure can be formed and hazards nipped before it constitute an accident. Hazards are transient and if not quickly identified and addressed it could lead to an accident. Along this communication channel is the reporting of near misses as well, so that all departments are aware and can avoid such situation from repeating itself.

The third trace of a company's commitment to occupational safety and health is the provision of resources that supports occupational safety and health targets. This includes providing tools and training to employees for detecting, evaluating, analyzing and controlling hazards. The company ensures that an organizational structure exist that guides the evaluation of safety due to changes to equipment and machinery and the necessary measures that needs to be considered in the purchase of machineries during change of operations or expansions. Also, the fourth element of a company's commitment to occupational safety is the policy that motivates and encourages employee to actively participate in issues of safety and health.

K.U and T.J Smith proposed the use of behavioral cybernetics theory for integrating ergonomics and occupational safety by encouraging the active participation of worker in all levels of operations, decision-making and feedback processes. The more freedom given the worker to influence operation's processes and identify hazards empowers him to become a resource for management decisions as regards ergonomics and operation's safety.

2.4.4 Tasks Factor

Smith identified the need for designing tasks that considers the physical, mental and psychological impacts they create to the mind and attitude of the worker. The most significant source of safety hazards is in the how to execute tasks. A job tasks which is not dangerous to the worker becomes dangerous only if the task is performed wrongly or with a different attitude. Tasks design have to be done with the considerations that it engages the mind and motivates the worker rather than clumsy and repetitive. A task that results in mental overload or underload numbs the attention of the work to an inherent hazard. Mental stress should be avoided as the worker is likely to make the wrong choices when he has to decide on issues of safety at work. The more monotonous and slow-paced a job task is, there is the tendency to engage the mind in other activities and not be able to identify hazards.

A Job task that exerts on the physical strength of the worker puts him right in the face of hazards. Excessive physical strength on a job can cause fatigue both mentally and psychologically and impede decision-making when the worker has to make one. Smith proposes analyzing tasks during design by engaging the worker and extracting his expertise on how best the job tasks could be carried out that involves the right mix of motivation, interest, mental awareness and physical strength.

2.4.5 Technology Factor

The use of machines and operational equipment must be accessed based on the compatibility between the machine and the worker. The suitability of the machine to the production's or operation's process is one determinant to the level of safety hazard inherent in the operations. Another determinant is the skill and knowledge the worker possesses in using the machine. Several reports of seemingly harmless machines that have caused work place accidents abound. The root cause in most cases is the lack of knowledge of the worker in handling the tools. This means that the organization must purchase equipment in which its work force can adapt to and can use effectively, efficiently and in a safe way.

2.5 Biomechanics and Material Handling

Biomechanics is the study of the impact of forces and loads on the human body using biological and engineering concepts and theory. *Biomechanics assumes that the human body behaves according to the laws of Newtonian mechanics* (Kroemer 1987). The object of interest of ergonomics in biomechanics at the work place is to be able to quantitatively assess the effects of loads and forces on the muscoskeletal frame of the worker in his work environment. Using this discipline, Ergonomists can quantitatively estimate the forces in the environment system and loadings acting on the worker and thereby evaluate the degree of risk exposure the worker engages himself in daily at work and what safety measures should be put in place. Work place biomechanical approach is often called industrial or occupational biomechanics. Chaffin (1999) defined occupational biomechanics as "the physical interaction of workers with their tools. Machines and materials so as to enhance the worker's performance while minimizing the risk of muscoskeletal disorders."

The objective of applying biomechanics principle to work center and tasks designs is indeed fundamental and revealing. The risks the worker engages with daily at work can be expressed scientifically using mathematical models and not just assumptions and vague ideas. This helps to estimate what safety measures the organization can put in place as well as how the work center can be designed to fit the worker.

However, it is an agreed knowledge in biomechanics that redesigning the work center to fit a part of the human body comes at a cost of compromising other parts of the human body. But biomechanics helps the designer estimate and manipulate quantitatively the trade-offs associated with work place risk factors to various parts of the human body in designing work place.

One underlying concept of occupational biomechanics is that during the design stage of the work center, care must be exercised in loading a structure so that it does not exceed the tolerance of the structure. This principle applies to designing tasks and machines for humans too. When tasks are overloaded it tends to strain the tissue tolerance (which is the permissible load the body tissues can withstand without inflaming or damaging them).

In occupational setting, trauma can assume two forms which can be damaging to the human body and lead to muscoskeletal disorders: Acute and Cumulative trauma

2.5.1 Acute vs. Cumulative Trauma

Acute trauma can occur when a single application of force is so large that it exceeds the tolerance of the body structure during an occupational task (Marras & Salvendy 2006, 340-342). When a worker lifts an extremely heavy object, there is the danger of exceeding his tissues tolerance which can lead to an accident or a muscoskeletal disorder. On the other hand, Cumulative trauma refers to repeated use of force in lifting, pushing, pulling of objects which builds up a wear and tear situation to the body tissues to the extent of lowering the tissue tolerances and eventually leading to muscoskeletal disorder.

The impact of acute trauma is immediate and devastating and may lead to permanent disability in a worker. This can be avoided if the worker does not endanger his health by lifting unnecessarily heavy loads in a show of strength and zeal. Cumulative trauma is symptomatic of repetitive tasks and can be difficult to break. The effect of this trauma is noticeable on the muscles and tendons which can cause irritation, inflammation and swelling of tendons. The muscles are impacted also by such repetitive tasks which can cause fatigue, inflammation and possibly muscle strains and tears. This can significantly lower the tissue tolerance and such people get tired quickly and their muscles give way under much lesser loads. This discomfort could run into days before the body repairs itself. However, the loss of a worker due to injury is already a loss to productivity for the company.

2.5.2 Moments vs. Levers

Another phenomenon to be considered in biomechanics is the moments and levers system of the body. As stated earlier, the body tends to obey Newtonian laws of mechanics. When the human arm lifts a load which is assumed to be 50-newton (N), at arm stretched length of 75 centimeter (cm) or 0,75 meter (m), it exerts a force of moment of (50*0,75) N.m on the shoulder joint of the body. However, the same load at an arm's length of 25cm or 0,25 m exerts a moment of (50*0, 25) N.m on the shoulder joint of the body. This gives insight into the dynamic biomechanics of the body at different loading positions even when the load is the same. Thus, load, even in the human body is not just a function of the weight only.

The body to be able to effectively carry loads acts like a lever in a machine. The joints of the body and spine serving as fulcrums in some cases, hence the body can assume first class, second class or third class levers task (Marras & Salvendy 2006, 340-344)

2.5.3 External vs. Internal Loading

Based on the lever system of the body, there two kinds of forces that can impose loads on the body tissues during work. These forces tend to balance each other so that they cancel each other out and the worker's body and load is in equilibrium. To achieve this, the body exercises the muscles to cancel out the external force which is both the load and gravity acting on the load. The muscles of the body exert a loading function called the internal force. While the external load and gravity form the external force. The cumulative trauma the body experiences are as a result of the body exerting the internal forces to support the tasks the worker engages in. Other relevant principles in biomechanics are;

- Impact of velocity on muscle force
- Strength vs. endurance
- Length-strength relationship

(Marras & Salvendy 2006, 340-344)

2.5.4 Body Load Tolerances

It is quite difficult to estimate the tolerances of bones, muscles, ligaments and tendons. Tolerances vary due to so many factors that vary from individual to individual, nationality to nationality and race to race. Furthermore, other factors like heredity, strain rate and psychology impede accurate measurements. The current tolerance figures are estimates derived from animals. They include;

Muscle and Bone Tolerances: the ultimate strength of a muscle has been estimated to be 32 MPa (Hoy et. al 1990), while tendon stress is estimated between 60 and 100 MPa (Nordin & Frankel 1989).

Ligament and Bone Tolerances: Ligament stress is estimated to be about 20 MPa while bone tolerance ranges from 51 MPa in transverse loading direction to 190 MPa in longitudinal loading direction (Ozakaya & Nordin 1991). The table below shows the summary of the findings (Marras & Salvendy 2006, 346-347). For other body tissues such as disc and vertebrae tolerances, there are dissimilarities in both men and women likewise.

Body Tissues	Estimated Tolerances $\boldsymbol{\sigma_u}$ (MPa)
Muscle	32-60
Ligament	20
Tendon	60-100
Bone longitudinal loading	
Tension	133
Compression	193

Shear	68
Bone transverse loading	
Tension	51
compression	133

Table 1 Tissue tolerance of musculoskeletal system (Ozakaya et. al 1991)

2.5.5 Applying Biomechanics principles in tools and machine handling

Biomechanical principles approach material handling from two factors: strength and compressive forces on the spine. Low back disorders (LBDs) are one of the prevalent muscoskeletal problems associated with occupational tasks. They account for 30% of work injuries in the United States where overexertion, lifting, holding, carrying, pushing and pulling of objects that weigh about 25 Kg or less by National Research Council (NRC 1999, 2001).

Manual materials handling (MMH) tasks account for most LBDs cases. About two-thirds of work-related back injuries arise from MMH tasks (NRC 2001). Although, there are still cases for arguments for the real cause of lower-back pain and ruptured or slipped discs of the spine. However, there is a general consensus that compressive forces acting on the L5/S1 disc in the spine poses considerable risk to the human spinal cord. Applying biomechanical solutions can address this compressive force during lifting and carrying of loads that impact the spinal discs.

Central to the biomechanics argument for lifting is the external load acting on the human system causing exertions and compressions of the body's spine. The back of the body is at a biomechanical disadvantage during lifting because the additional muscular forces generated to support the external load comes from the trunk, otherwise the load, which tends to follow a momentum would tilt and fall over causing more severe damages. Simply, for the body to maintain the equilibrium of forces in the lifting system, internal loading must cancel out the external loading. This means that much internal compressive force is generated which compressively puts the spine at a disadvantage. Some literature had recommended various lifting styles such as lifting using the “legs” or using the “Stoop method”. Park and Chaffin, (1974) and Van Dieen (1999), demonstrated that no lifting style is ideal for all body types.

The National Institute of Occupational Safety and Health (NIOSH 1981), has concluded that tasks generating more than 650 kg of compressive force to the lower back are hazardous to all but the healthiest workers. However, NIOSH has stated that lift style should not be a consideration when analyzing risks during material handling. Biomechanics has recommended that the correct lifting style is whatever position permits the worker to bring as close as possible the center of mass of the object to the spine of the human body (Marras et. al 2006, 346-358).

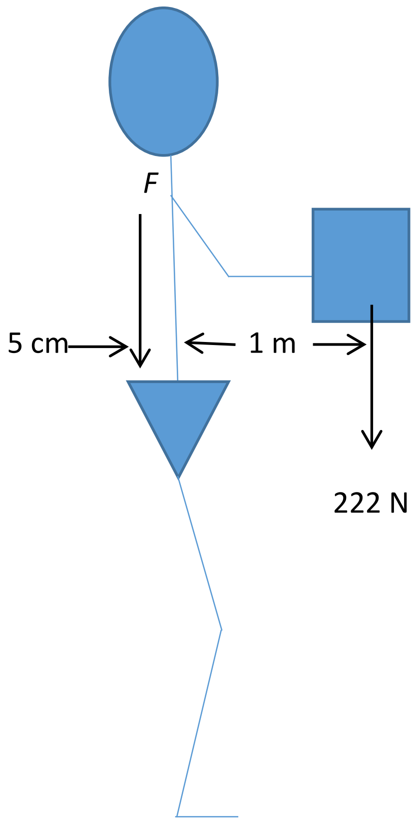

Figure 5 Internal muscle force required to counterbalance an external load during lifting. (Marras et. al 2006.)

$Internal\ muscle\ force\ F,$

$F.5cm = 222\ N.1m$

$$= \frac{222N.m}{0.05m}$$

$$= 440N$$

2.5.6 Other Guides to Correct Manual Material Handling

There are other instructions and regulations for workers who engage in physically demanding tasks which must be adhered to in materials handling. One of those is the Health and Safety at work employee responsibility (HASAWA 1974), which states clearly the duties and responsibility of the employer and employee in handling heavy materials or machines. The regulations 4 summarize thus; the employer shall not subject if practicable, the employee to materials handling tasks that involves risk of injury to the employee. The employer shall;

I. Make suitable and sufficient assessment of the load;
II. Take all measures to minimize the risk In the operations
III. Provide detailed information (such as weight and dimension) of the material to the employee for proper awareness of the risks.

The European Heavy Loads Directives supplements the HASAWA regulations. The following instructions also help in proper material handling;

- Correct grip of the load
- Straight back when picking up a load.
- The head should be positioned up prior to every lift
- Arm should be close to the body while having the load suspended
- Correct foot positioning
- In moving, or pulling loads, the body weight can act as support.

(Stranks 2010).

2.5.7 NIOSH Lifting Equation

In 1981, the National Institute for Occupation Safety and Health (NIOSH) published a series of recommendations to guide workers when lifting objects at work places. The assumptions to this practical guide were that the object to be lifted should be symmetrical, moderate width and smooth. The recommendations were made based on two identified levels of hazards and three criteria for being safe and avoiding injury during lifting of materials. If these criteria are not fulfilled, then the worker should not risk lifting the load. The hazards likely to be engaged from lifting unpermitted loads are;

a) Maximum permissible limits (MPLs), which is based on a biomechanical criterion that the force of the load should be not more than 6400 N force of compression on the spine of the carrier. A psychophysical criterion that indicates that 1% of women would accept to lift the load and 25% of men. And a physiological criterion that lifting the load does not cause aerobic (energy) fatigue and muscle fatigue at 5 Kcal/min.
b) Action limit (AL), which is based on biomechanical criterion that the load does not cause over 3400N compressive force on the spine of the carrier, a physiological criterion of 3.5 Kcal/min and a psychosocial criterion that 75% of women and 95% of men would accept to lift the load.

However, the regulation was revised in 1991, and the *recommended weight limit* (RWL) equation introduced. The weight limit was introduced to protect 90% of the mixed (male/female) industrial working population against lower back pains (LBP). (Waters et al. 1993.)

The equation is based on three components;

- The standard lifting location
- Load constant
- And risk factors

Summarily, the equation applies thus;

$$RWL\ (kg) = LC \times HM\ \times VM\ \times DM\ \times AM\ \times FM\ \times CM$$

Where;

LC is the load constant, which refers to the maximum weight value of the standard lifting location as specified by the NIOSH guide. The multipliers (M) are defined in terms of the related risk factors where

- HM is the horizontal location,
- VM the vertical location,
- AM is the asymmetry angle
- DM is the travel distance
- CM is the coupling
- And FM is the frequency of lift.

These multipliers are defined by the revised NIOSH guideline (Karwowski et al. 2001.)

2.5.8 Seated versus Standing Workplaces

The lower region of the spine called the lumber region consists of 5 vertebrae labeled L1, L2, L3, L4 and L5. This region is around the waist and ensures human can bend, twist and turn easily. Researches have established that the load on the lumber spine is greater when a worker is seated than when standing (Anderson et al. 1975). There are chances of damaging one or more intervertebral disc from prolonged and wrong sitting posture. Hence, a job that involves more of sitting puts the worker at greater risk of lower back pain from overloading the lumber spine when compared to standing. However, an ergonomically designed chair can minimize this effect.

Very few knowledge exist about the effects of prolonged standing on the lower back. Aside from fatigue to the muscles of the legs which can be dampened by switching from resting on one leg to the other, no known effect from prolonged standing are obvious. Hence most organizations have favored standing tasks and jobs than seated ones. The following are reasons why standing workbenches are preferable to seated ones;

- The tasks requires a high degree of mobility,
- Heavy weights are handled,
- Precise manual control actions are not required

- And no affordable leg room

(Marras & Salvendy 2006, 346-347).

2.6 Situation Awareness

Maintaining a high level of awareness and knowledge of situations in an operating environment of vast amount of information is turning out to be more difficult and challenging for most maintenance persons. Concentration on what information is important and what is not in a rapidly dynamic environment can require a high level of concentration and discipline, especially in a 21st century of phenomenal technological changes and growth.

In the study of accidents in the aviation industry, 88% of human error was attributed to problems with situation awareness (SA) (Endsley 1995c). The highly held misconception that human error accounts for most accidents is pushing the bulk of the accident to an individual and sweeping the real issues under. The solution lies in how human processes the vast amount of data in his environment to make informed decisions that alters the flow of his environment.

Situation awareness*, perceives critical factors in the environment, understanding what those factors mean, particularly when integrated together in relation to the operator's goal, and at the highest level, an understanding of what will happen with the system in the near future.* (Endsley 1988). The definition highlights three levels of mental activity of the mind to achieve a successful SA;

First level is perception: the maintenance technician, aircraft pilot or machine operator must perceive the dynamics and trends in his operating environment to achieve the first level of SA.

Second level: the level at which sufficient evidences can be drawn from disjointed information and forming a holistic picture of the system in the mind of the human. In this level, the human comprehends and knows the significance of elements and information in the system enough to make decisions when required towards achieving the goals of the system.

Third Level: Projecting the future dynamics of the system arises from having a clear picture of the whole system and comprehending the changing elements of the system. This is what puts the operator in control of the situation surrounding him.

To develop one's situation awareness in a system requires the involvement of one's cognitive and mental skill. Experience and expertise can help fasten one's development of situation awareness process. A novice put in a complex and dynamic system stands no chance of achieving the goals of the system because he has little working memory of the processes and may not know when to act or will make decisions that impedes the system's success. Having a comprehension of how the system works from years of work enhances the working memory, short term memory, perception and longtime memory in enhancing SA and puts the operator/technician in pole position to become aware of his situation awareness, interpret dynamics of the system and predict the near future of the objectives of the system. This model of enhancing SA is based on information-processing theory.

Alternatively, the operator's goal also plays an important role in SA process, and this is known as goal-driven processing in SA. Goal driven model is the ideal state of the system the human wishes to achieve. The human must balance his perception and attention between goal-driven and data-driven process in developing his SA. Focusing on goal-driven process model alone could mean that the human runs the chance of missing important information that could change the goal of the system. However, focusing on data analysis of the system purely could equally mean that dealing with an explosion of data alone could lead to misinterpretation of the system and loss of understanding of the dynamics of the system. Hence the human (operator or technician) should balance between developing his SA through both models in acquiring information about the system (Endsley & Salvendy 2006, 528-539)

2.7 Human Error and Accidents

Meister (1987) defines accident as "an unanticipated event which damages the system and/or the individual's task". This is an all covering definition especially in the context that most accidents are synonymous with injury, which is usually not the case. As much as accidents affect humans in terms of injuries and death, they also affect the tendency of the worker to perform his job well if the system is damaged.

The statement that most accidents' cause is traceable to human error is not entirely true. As stated earlier, *human error is an inappropriate or undesirable human decision or behavior that reduces, or has the potential for reducing effectiveness, safety or system's performance* (Sanders & McCormick 1993). From this definition, an error becomes definitive if it has the tendency to undermine system's performance and people's health and safety. Other factors do contribute to accidents and injuries at work. Bad design of tools and machines can have a negative effect on worker's ability to act safe at work. Equally, the attitudes of co-workers, poorly designed tasks without consideration for human capacity to execute them and poor man management skills can have impacts on the frequency of human error and consequently accident. The very popular question most ergonomists have asked in correcting human behavior in working system is: "what percentage of accidents is caused by human error. The tendency to always blame human unsafe acts can be influential in arriving at an answer to this question. However, there are various accident causation theories compounded to give insight to the understanding of human behavior and accident. (Sanders et al. 1993, 660-663.)

2.7.1 Accident-Proneness Theory

This theory hypothesizes the tendency of some people to be more prone to accidents than others because of a distinct set of characters which is natural to them. This theory has been countered severally with other researches which has seen smarter and less accident prone people fall into this accident prone group. Hence, the new theory called the *accident liability theory* which states that people are more or less prone to accidents depending on the situation, and the level of proneness changes over time. The evidence of this theory is the high frequency of accidents among young workers when compared with their aged counterparts (Shahani 1987). Young people tend to be less disciplined, impulsive and reckless in making decisions. But a contributing research found an increasing rate of accident among workers between the ages of 50-60. Although this is far less when compared to younger workers (Shahani 1987). The reason for this is due to deterioration in motor skills, sensory functions, and mental agility (DeGreen 1972). This statement better explains this theory: “accident liability changes with time”.

2.7.2 Job Demand vs. Worker Capability Theories

These set of theories recognize human limitations as the cause of accidents. These theories postulate that when work demands exceed the worker’s capability, accident is inevitable. In this category of theories, is the *adjustment to stress theory* which states that the likelihood of accident is high if job stresses exceed the capability of workers to meet it. (Sanders & et al. 1993, 660-675).

2.7.3 Psychosocial Theories

This theory emphasizes the interpretation of accident as a low performance when workers are given the freedom to set reasonable achievable goals to reach high performance and high quality work ethics (Kerr, 1957). (ibid. 660-670)

2.7.4 Factors Contributing to Accidents

Sanders and Shaw (1998) proposed the model of *contributing factors in accident causation* (CFAC). This broad model identifies all root cause of accidents in the work environment. The model recognizes the human-machine relationship, the environment system and the organization’s commitments and policies. The factors identified by CFAC crucial to accident causation are;

- Management (policies, safety orientation, incentive system, employee development)
- Physical environment (noise, temperature, humidity, illumination, architecture, work space, distractions, pollutants)
- Equipment design (controls, display, visibility, mechanical and electrical hazards)
- The work (physical and mental workload, boredom, shift work, methods, rest schedules)
- Social/psychological environment (group norms, morale, communications, union relations)

- Worker/coworker (ability level, alertness, experience, training, fatigue, age, intelligence, illness, job satisfaction, physical capabilities)

3 Occupational Safety and Health Regulations

There are various documents, standards and acts that have been formulated over the course of many industrial years that support and regulate the safety of workers, machines and the operating environment. A commitment to these documents from member-countries, firms and labor organizations is prerequisite to ensuring quality control, process management and equality for all organizations in international operations.

A *standard is a documented agreement containing technical specifications or other precise criteria, to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for the purpose served by those making reference to the standard* (ISO 2004). Standards can be classified into three broad categories;

- International Standards (provide basis for worldwide standardization, and includes the International Standard organization (ISO), International Electrical Commission (IEC) and International Telecommunications Union (ITU).
- Regional standards (these organizations aim to provide a coherent and voluntary set of standards suitable for a single regional market, and includes the European Committee for standardization (CEN) amongst other bodies, European Committee for Electrote-chnical Standardization (CENELEC) and European Telecommunications Standards Institute (ETSI) .
- And national standards (this is the coordination of standards in national level by formulated national bodies. Examples are the British Standard Institute (BSI), Deutshes Intitut für Normung (DIN) and the American National Standard Institute (ANSI).

The International Standard Organization in 1975 formed a technical committee named TC 59 to develop standards for the field of ergonomics (Parsons et al. 1995). The standard, coded ISO/TC 159 promotes the adaptation of working and living conditions to human well-being by considering the physical, sociological, and technological environment he operates in. The objective of this committee was to come out with a document that addresses the safety, health, well-being and effectiveness of people in their places of work.

3.1 European Agency for Safety and Health at Work (EU-OSHA)

The European Agency for Safety and Health at Work is an agency in the European Union entrusted with the tasks of promoting safety, health and well-being of workers in the EU through collection, analyzing and dissemination of relevant information that forms the guidelines for member countries to make legislations that protect people in their work places. The culture of preventing risks is seen as critical to the enhancement of safe working environment. EU-OSHA engages in educational researches to identify main stream occupational safety issues as well as emerging risks and trends in the workplaces likely to endanger lives or health of people.

The European occupational safety and health legislatures and documents contain directives, guidelines and standards for member-countries to use as instruments of law and legislations formulation in their own nations. These documents set standards and parameters for such issues as:

- Permissible noise level at work places,
- Permissible level of vibration,
- Illumination,
- Materials and tools handling,
- Exposure to hazard and risk assessment,
- Visual displays,
- And the use of Personal Protective Equipment (PPE).

3.2 Finnish legislations on Occupational Health and Safety

The first Occupational Safety and Health Act was formulated in 1958 which shows the commitment of the government to ensuring safe and healthy work conditions for the citizens. The Occupational Safety and Health act 2002 is the recent document in compliance with the EU guide, directive and standards for ensuring workers' health and safety (FINLEX 2002).

The objectives of the act (2002) are to improve the working environment and working conditions so as to ensure the working capacity of employees. The act aims to also eliminate hazards associated with workplaces and work environment as well as prevention of occupational accidents and diseases. The physical and mental health of employees is considered central to this Act also. The act states in clear terms the obligations of employers in ensuring that their employees are protected from hazards and risks associated with their jobs. The employer must display unreserved commitment to formulating policies that incorporate the development of working conditions and environmental safety in their operations. For example, the employer must make adequate provisions for Personal Protective Equipment and safety devices in cases when required as the job demands (the Safety and Occupational Act, section 15, article 3). The Act as well specifies the responsibilities and duties of the employee at workplaces. According to the Act, ergonomics considerations for work environment, space, ventilation, lighting, material handling, safety of machines and treating of biological wastes must be assessed and complied with according to the Act (Finnish Ministry of Justice).

4 Evaluation of Client's Equipment and Process

Speed Autokorjaamo boasts of modern equipment, tools and machineries with which services and maintenance operations are done. The work center consists of three work sections each equipped with lifting machines, electric- powered machines and tools, pneumatic and hydraulic powered machines, manual handling tools and gas-powered machines like the welding machine. The current system, process and equipment were evaluated to gain an overall picture of the maintenance operations which formed the base for risk assessment of the company. The exercise also provided answers to the theoretical question of what hazards and risks visible and hidden were in the present operations and process of the company.

The evaluation included interviews, participatory observation and a research into the manufacturer's manual for operating this equipment. The evaluation included;

- Installations, operations and handling risks in the lifting machines both pneumatic and hydraulic,
- The risks in the use of hand tools, electric powered tools and gas powered tools,
- Lighting and illumination,
- The use of personal protective equipment (PPE),
- The noise level in the maintenance operations,
- The vibration level in the present operations,
- Load lifting and handling procedures,
- Wastes handling and waste disposal methods adopted by the company in the current operations.

4.1 Installations, operations and handling risks in the lift machines

In the company's work center as mention earlier is divided into three work sections. Each section of the work center has a different kind of lift to meet the required service for which the work space is suitable.

4.1.1 Work Section 1

This work center is equipped with a four-Post electro-hydraulic lift from STENHØJ Company, a Danish leading manufacturer of automotive lifts, compressors, hydraulic presses and parts cleaners. If a lift is classified as a four-post lift it simply means that the equipment is fortified to the floor by four standing posts. This is to give equilibrium and balance to the lift so that it can support whatsoever weight it is designed to carry. The lift is designed to carry 2.5 tons load and comes equipped with drive-on ramps. It is most suitable for jobs that involve wheel alignment, service and inspection, repair of brakes, wheels, exhaust system, shock absorbers transmissions and differentials (STENHØJ, 2014).

The safety system in the lift includes:

- Mechanical safety catch bar,

- Automatic soft lowering for the last 150 mm above floor,
- Acoustic warning signal when lowering,
- The equipment is installed with 6 pieces 20 mm studs screwed to a fortified foundation at each posts.

The work section is also fitted with hand tools which are considered safe depending on the knowledge of the user in handling these tools.

4.1.2 Work Section 2

Section 2 is equipped with a lifting machine from Nordlift Oy a Finnish electro-hydraulic manufacturer. The lift is a One-post type equipment positioned at angle that ensures easy accessibility of the work area for the technician and an optimum utility of work space. According to the manufacturer, the one post lift can lift 3 tons of load, at a lifting height of 1900mm. The telescopic four arms allow for adjustments to all kinds of cars.

The safety system in the one post-lift are;

- 20 cm reinforced concrete foundation,
- 8 pieces of 18 mm bolt studs fastening the post to the floor,
- Automatic arm lock system,
- Flow control valve,
- Control box with dead-man controls,
- Independent working mechanical lock,
- And run ups with roll back protection.

(Nordlift Oy 2007)

The work section is equipped with electric-powered tools, hand tools as well as pneumatic-powered tools which are most suitable for car body works, welding, spraying, metal grinding, cutting, inspection and dismantling of whole engine systems in cars and other intensive tasks. The safety of the work section depended on the expertise and knowledge of the technician in operating the whole unit.

4.1.3 Work Section 3

Section 3 is fitted with a two-post lift provided by NHT, a Chinese electro-hydraulic lift manufacturer. According to the manufacturer, the lift has asymmetrical arms and can support a load of 3.6 tons to a lift height of $1850mm$. The equipment comes fitted with 2.2 Kw motor for supplying hydraulic power to run the lift. However, very few information exist about the safety of the equipment from the manufacturer. The followings are the author's observations and inferences about safety of the equipment from operating it:

- Independent lock system for suspension if the car at any height,
- Hydraulic flow control valve,
- Adjustable arms for supporting any load dimensions,
- Floor reinforcement and studs for holding the equipment firmly to the floor.

This work section is equipped with all kinds of tools suitable for short-term quick jobs like tyre changes, brakes inspection and change, car oil change, checklist inspection for onward approval to car inspection centers. The safety of the work section depends on the knowledge of the technician.

4.2 Use of Personal Protective Equipment (PPE)

The company has made efforts to provide Protective clothing, goggles, hand gloves, safety shoes, body harness and helmets during work. These items are made available to all staff when working on the job. However, there are no defined restrictions to when and where some of these equipment's are required. Neither are there warnings or reminder signs to inform new staff and visitors about the need to protect self by complying with the rules if they happened to be walking around the company's property.

4.3 Lighting and illumination

The lighting of the work sections and the company property are sufficient enough for technicians and operators to carry out their tasks without having to resort to other sources of light.

4.4 Noise and Vibration levels

Risks from vibrations can be analyzed from two approaches: the vibration limits of the machines and the vibrations permissible limits to the human body. According to the Machinery Safety Directive of the European Community (EEC 1989), a machine must be designed so that hazards resulting from vibration produced by the machinery are reduced to the lowest practicable level. The current limit for vibration from machine is at a frequency-weighted acceleration of 0.5 $/s^2 \ \ rms$.

In 2002, the Parliament and Commission of the European Community agreed on a minimum health and safety requirements for the exposure of workers to risks from vibration. A worker's whole body vibration for an 8-hour exposure action period is 0.5 $/s^2 \ \ rms$ and an exposure limit of 1.15 $/s^2 \ \ rms$. If the exposure action values are exceeded, the employer must implement measure and actions to reduce the vibrations to mechanical vibrations and attendant risks (EEC 2005). These limits have not been exceeded by machines and maintenance operations in the company presently. (Salvendy et al. 2006.)

According to OSHA noise regulations (1983), the noise exposure limit is both a function of the intensity and duration of noise exposure. The Permissible Exposure Limit (PEL) is 90 dBA (A-weighted decibels) for an 8-hour work period. When the noise level is at 95 dBA, the allowable exposure per work day should be 4 hours. Speed Autokorjaamo has complied with this regulation which is also enforced by the Finnish Occupational safety and Health Act.

4.5 Waste Handling and Disposal Methods

The company makes adequate provisions for disposing wastes from maintenance activities. The wastes most identifiable with car maintenance are Oil wastes, metal scraps, unused car spare parts, degreasers, tin cans, scrap tyres, antifreeze liquids, used oil filters and used lead-acid batteries. The company in compliance with Finland's Environmental Protection Act disposes the wastes by measures considered harmless to the environment. The company does not dispose used oil or other liquid wastes to drains. Neither are bad tyres burnt under any circumstances. Metal scraps are moved to metal yards for onward recycling.

4.6 Load lifting and Handling Procedures

The company has not made adequate provisions for ensuring workers are aware of the guidelines, directive and procedures for lifting and handling materials as specified by National Institute for Occupation Safety and Health. Technicians are verbally informed about the risk of lifting loads heavier than the capacity of the worker, however, in no case was there any information of the limits of load he could carry, the correct procedure for lifting or pushing, and consequences of lifting or pushing loads too heavy for him. The responsibility of the company and employee as stated in the Health and Safety at work (HASAWA) responsibilities' directives (1974) have not been fully explored.

5 Results and Analysis

For the purpose of this thesis, the need to define hazard and risks was needful in making a risk assessment of the client's operations. Hence the author had identified the possible hazards in the operations and which of these hazards constituted a risk to human health and safety, and the environment. The risk assessment did not evaluate risks to business process, machines and equipment of the client since the thesis was limited to safety of human at their jobs. The assessment process formed the answer to the first research question of what risks factors and hazards visible and hidden existed in the present maintenance operations.

5.1 What are the risks factors and hazards presently visible and hidden in the maintenance operations?

According to Christensen (1987), *Hazard could be defined as a condition or set of circumstances that has the potential of causing or contributing to injury or death*.

Hazards can be categorized into the following groups:

- Biological Hazards: these include bacteria, virus, humans, and animals.
- Psychosocial Hazards: stress, harassment, loneliness, job dissatisfaction.
- Chemical Hazards: chemical and toxic wastes and materials.

- Physical Hazards: noise, vibrations, inadequate illumination, radiations, dust, improper ventilation, falling objects, welding.
- Ergonomics Hazards: badly designed work station, repetitive movements, poorly designed tasks, frequent lifting.
- Safety Hazards: slipping/tripping, confined space works, naked electric wires, work at height, on ladder, scaffolds, and faulty machines and equipment (Occupational Safety and Health Organization).

Risk is the probability or likelihood of injury or death. The European Union agency for safety and Health at Work (EU-OSHA) defines risk as: the chance, high or low that somebody may be harmed by an unattended hazard.

In risk assessment process, the following steps are taking:

Classify work activities
↓
Identify hazards
↓
Determine risks
↓
Decide if risk is tolerable
↓
Prepare risk control action Plan (if necessary)
↓
Review Adequacy of action plan

(Stranks 2010, 68)

Following this guideline, the following evaluations were made of the company as shown below. The charts indicated the level of hazard exposure from activities of the operations of the company and the severity to human lives.

For the purpose of this study, the following was the score method for quantifying each event

5.1.1 Probability

The probability of the event happening shall be graded by:

0 = not applicable 1 = low level chance 2= medium

3 = high chances of happening

5.1.2 Severity

Severity is the human and system damage from an accident happening due to a hazard. In this study it was human impact and internal response to accident happening.

The grading scale for severity shall be

0 = not applicable 1 = low level impact 2= medium level impact

3 = high level impact

5.1.3 Risk

Risk shall be graded in percentages of likelihood of impact to human and system functionability.

With the percentages classifications of the risks, the implications of each risk to the company's operations helped give insights into the current state of the safety and health of workers and what measures needed to be taken to ensure employee safety.

the variables are expressed in the equation below:

$$Risk = Probability * severity$$

$$Severity = \frac{human\ impact + Internal\ response}{no\ of\ possible\ outcomes\ (6)}$$

Risk shall be expressed in percentages.

Mild risk < 30% medium risk < 50% high risk > 50% or more

5.1.4 Internal response

This is the level of response in terms of personnel and resources to prevent a risk from happening or degree of response to the accident that has occurred. This shall be graded in

1= no response 2= inadequate response effort 3= high response.

5.1.5 Physical Hazards

Event	Probability	Human Impact	Internal Response	Risk
Noise from revving car	3	3	1	67%
Noise from cutting machine	3	2	2	67%
Extreme hot temperature	3	3	1	67%
Extreme cold temperature	2	1	3	44%
Vibration from equipment	3	1	1	33%
Inhaling dust particles from engines	2	2	1	33%
Fires from spilled flammable liquids	1	3	3	33%
Punctures and cuts from hand tools, car parts and sheet materials	3	3	1	67%

Table 2 Physical Hazard Assessment

5.1.6 Chemical Hazards

Event	Probability	Human Impact	Internal Response	Risk
Carbon monoxide Poisoning	3	3	1	67%
Exposure to asbestos dust from brake drums	2	3	3	67%
Inhalation of diesel exhaust fumes	2	2	1	33%
Exposure to degreasers, detergents and metal cleaners	3	2	1	50%
Splashes of corrosives and adhesives causing skin irritation	1	1	1	11%

Table 3 Chemical Hazards Assessment

5.1.7 Safety Hazards

Event	Probability	Human Impact	Internal Response	Risk
Falls from ladder	1	3	3	33%
Falls from slippery or wet surfaces	3	3	1	67%
Injuries from rotating parts	3	3	2	83%
Electrocution	1	3	3	33%
Burns due to contact with hot surfaces	3	3	1	67%
Exposure to Ultraviolet from welding machine	3	3	1	67%
Crushed toes resulting from fall of heavy objects	1	3	1	22%
Injuries from failures of lifts and jacks	1	3	1	22%

Eye injury from metal dust and splinters from machine grinders	3	3	2	83%
Car tyres bursting	1	3	1	22%

Table 4 Safety Hazard Assessment

5.1.8 Ergonomics Hazard

Event	Probability	Human Impact	Internal Response	Risk
Muscoskeletal injuries (lower back pains)	3	3	1	67%
Fracture or dislocation from lifting excessive load	3	3	1	67%
Accident from working in confined space	2	2	1	33%

Table 5 Ergonomics Hazard Assessment

On average, the risk of each type of hazard in the company weighed at over 50%. These showed that measures needed to be implemented to minimize or erase these risks and the danger they posed to the operations of the company.

5.2 What are the explorable options to improving ergonomics and work safety?

Ergonomics interventions as a means of enhancing safety and health at work places can be wholesome and demanding. Often, it is more appropriate that an ergonomist is involved in the whole planning process of business operations, this is because rectifying faults and discomfort at work can be cost intensive. The following are approaches to enhancing safety in maintenance operations at Speed Autokorjaamo.

5.2.1 Work center redesign

This approach emphasizes viewing human and his work place from the work system approach. The goal of this method is integrating all the elements of the work system into a synchronized unit aimed at achieving the goals of the entire system. The elements are:

1. Work tasks
2. Tools
3. The work environment
4. Physical, chemical, biological social and cultural conditions
5. The human.

Work center design aims at optimal coaction of humans, tools and work tasks (Spath, Braun & Lorenz 2006). Redesigning a whole process would mean taking into account the need to plan reinstallations of equipment and machineries, a redesign of work tasks, so that the work motivates the technician as well as put into consideration his capacities. Tools will be discarded if need be and new tools purchased that are suitable for the worker and are ergonomically designed.

5.2.2 Biomechanics Approach

The need to make paradigm shift from the mindset that maintenance activities are physically exerting tasks enhances the process of thinking about solutions to manual materials handling. The more reason there are less women maintenance technicians is the general views held in the industry that the tasks are most suited for the strength of men. When constant or heavy lifting is avoided, stress and pain in the lower back can be reduced.

As mentioned in the theory, a complete risk assessment of load to be lifted needs to be done always and a procedure for evaluating the available options to manual materials handling needs to be documented and adhered to. The company can equally make available the following;

- Adequate motion range for load handling,
- A supply of lifting utilities like lifting belt, lifting platforms, pushing trolleys,
- Favorable load lifting with deposition heights between 70 and 100 cm above ground

- Adequate relaxation time.

(Spath et al. 2006)

5.2.3 Safety Drills, Warning Systems and Floor Marking

Warning signs at work place are a narrow way of informing workers on safety. Warnings can take a larger concept than signs and symbols on walls. Tools, machines and equipment can be embossed with warnings and instructions for improper use. This concept can be applied equally to manual material handling and operating lifts. An automated light blinker or alarms informing the lift operator of exceeding the permissible height for lifting certain loads help prevent accidents.

Floor marking is adapted from the manufacturing industry. The floor marks show restricted areas, gangways, forklift pathway, pedestrian pathways and products storage space. Exploring this option helps limit roaming in the company and movement of materials and equipment to wrong locations. This can be applied to the work center at Speed Autokorjaamo. Designated spots for hot spare parts, grinding and metal cutting machines, slippery surfaces where used oil are spilled can help minimize accidents.

Safety drill is a safety exercise meant to prepare workers for workplace accidents like fire and natural disasters. The purpose is that all workers are aware and prepared in the eventuality of an accident.

5.2.4 Safety Management Systems

Safety management system is a systematic approach to managing safety, risks and health issues at work. The Occupational Health and Safety Assessment Series (OHSAS 18001 & OHSAS 18002) are two British safety management systems that help form a framework for assessing and ensuring workplace safety and occupational health.

International Standard Organization ISO 9001 (Quality Management system) *provide guidance and tools for companies and organizations who want to ensure that their products and services consistently meet customer’s requirements, and that the quality is consistently improved* (ISO 2008). This system along with ISO 14000 (Environmental Management

System) provide tools for a company to comply with environmental standards and obligations in their operations. The processes for obtaining these two certifications follow certain set rules and procedures. This can be overwhelming for a company the size of Speed Autokorjaamo but, it is not unachievable.

5.3 Is it possible to integrate these options and at what cost to the company?

Currently, the client has a high employee turn-over; an employee turn-over is the rate at which a company replaces employees. This situation however, has little consequences on the client's budget. This is because the company requires highly skilled technicians in the expertise of car maintenance, there are few technicians vastly skilled in all car models' maintenance technical know-how. Hence Speed Autokorjaamo has few full-time technicians and is open to practical training for engineering students from the university so that although employee turn-over is high, the cost of recruitment is minimal.

5.3.1 Option 1: Safety management Systems and Costs

The cost of obtaining OHSAS 18001 and 18002 or ISO 14000 and ISO 9001 certifications can be tangible considering that Speed Autokorjaamo is a SMEs. The process for certification requires a series of audits, trainings, operations redesigning, surveillance, re-auditing, and reporting. This can be cumbersome and overwhelming on the budget of the client. Hence this option is high up the shelf.

5.3.2 Option 2: Integrating Biomechanics Approach, Warning Systems and Work Center Redesign and Costs

Slight Ergonomics changes can have considerable impact if the need of the work system is correctly defined. From the results of the risk assessment, the highest risk situations are those the company can make considerable changes in operations without having to incur high costs. For example, according to the risk evaluation, eye injury from metal splinters accounted for one of the highest risk situation. In this case, the company could introduce a warning system on the grinding machine that makes it noticeable to always use the protective eye glasses when operating the machine.

Equally, a process of tools evaluation of all tools can be done to identify what tools are compatible with the human. Certain tools put the human under considerable strain when using them. The process helps identify tools most suited for tasks, and when these tools are marked or classified into a group and a place, the technician knows where and what tools to use for what job to be done.

The client may not be able to redesign the work center, because this would require dismantling equipment and machines and reinstalling them which comes at considerable cost to operations and services to customers, but the company can redesign work tasks to the capabilities of the human. The task must be such that it motivates the worker and encourage him to get involved in the goals achievement.

Proper materials handling training and procedures needs to be documented so that loads are lifted and carried in compliance with NIOSH guideline. This will in the long run reduce the effects of lower back pain (LBP). A document outlining these guidelines can be posted in each work sections to serve as a constant reminder of the need to work safely.

6 Recommendations

The cost of option 2 is not beyond the company's budget. The changes and recommendations stated are reachable and achievable. Materials such as lock-out and tag-out materials, warning posts and floor markings can be sourced for and are available. Creating a management system requires a constant process of auditing, documentations and planning, because changes are constant and hazards are dynamic. It is as well challenging especially when it is new and has to be tailored to the company's operations. However, the option the author favored requires both human and system's involvement to achieve a workplace devoid of hazards and risk. In reality risks and hazards cannot be completely eliminated but they can be minimized. This can become a spring board for the company towards creating a safety management system most suited to the operations of the company.

6.1 Bench-marking

Benchmarking is a form of measuring an organization's performance by measuring their operations against set standards obtainable in the industry (Stranks 2010, 70). The author through interviewing and sending questionnaire to prominent car dealerships and auto shops sought to gather relevant information that would help him form a suitable management system that is in standard with what is obtainable in the auto industry in Finland. However, the result of this exercise showed that each company had a safety management system tailored to their operations. Hence, there was no defined industry standard.

7 Conclusion

The goal of the research was to apply the appropriate principles of human factor and Ergonomics to creating a safety management system consistent with the nature of the client's maintenance operations with regards also to the company's financial budget. The safety plan has been created using the principles derived from Options 2 (stated above). This document is a series of guidelines that technicians can follow while working to maintain self-safety and well-being.

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